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05MAR01 E610918-1 D00370
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1. Your reference

DY2858

2. Patent application number
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0105349.5

- 3 MAR 2001

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

ROLLS-ROYCE PLC

65 BUCKINGHAM GATE
LONDON
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Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

ENGLAND

3970002

4. Title of the invention

GAS TURBINE ENGINE EXHAUST NOZZLE

5. Name of your agent *(if you have one)*

M A GUNN

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

ROLLS-ROYCE plc
PATENTS DEPARTMENT
PO BOX 31
DERBY
DE24 8BJ

Patents ADP number *(if you know it)*

3962001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Claim*(s)*	7
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Drawing*(s)*	7 ~~7~~ 7

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Request for preliminary examination and search *(Patents Form 9/77)*	1
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Any other documents *(please specify)*	DEPOSIT ACCOUNT FEE SHEET ✓

11. I/We request the grant of a patent on the basis of this application.

Signature M A GUNN Date 2.3.2001

12. Name and daytime telephone number of person to contact in the United Kingdom K A WHITE 01332 249452

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Statement of inventorship and of right to grant of a patent

The Patent Office

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2. Patent application number
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   0105349.5 - 3 MAR 2001

3. Full name of the or of each applicant

   ROLLS-ROYCE plc

4. Title of the invention

   GAS TURBINE ENGINE EXHAUST NOZZLE

5. State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent

   BY VIRTUE OF AN AGREEMENT DATED 28 FEBRUARY 2001

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Patents ADP number *(if you know it)*:

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GAS TURBINE ENGINE EXHAUST NOZZLE

The present invention relates generally to gas turbine engine exhaust nozzles, and in particular to noise reduction and performance improvements to nozzle arrangements used for gas turbine engines suited to aircraft propulsion.

Gas turbine engines are widely used to power aircraft. As is well known, the engine basically provides propulsive power by generating a high velocity stream of gas which is exhausted rearwards through an exhaust nozzle. A single high velocity gas stream is produced by a turbojet gas turbine engine. More commonly nowadays however two streams, a core exhaust and a bypass exhaust, are generated by a ducted fan gas turbine engine or bypass gas turbine engine.

The high velocity gas stream produced by gas turbine engines generates a significant amount of noise, which is referred to as exhaust or jet noise. This noise is generated due to the high velocity of the exhaust stream, or streams, and the mixing of the streams with the surrounding atmosphere, and in the case of two streams, as the bypass and core streams mix. The degree of the noise generated is determined by the velocity of the stream and how the streams mix as they exhaust through the exhaust nozzle.

Increasing environmental concerns require that the noise produced by gas turbine engines, and in particular aircraft gas turbine engines, is reduced and there has been considerable work carried out to reduce the noise produced by the mixing of the high velocity gas stream(s). A large number of various exhaust nozzle designs have been used and proposed to control and modify how the high velocity exhaust gas streams mix. With ducted fan gas turbine engines particular attention has been paid to the core stream and the mixing of the core and bypass exhaust

streams. This is because the core stream velocity is considerably greater than the bypass stream and also the surrounding atmosphere and consequently the core exhaust stream generates a significant amount of the exhaust noise. Mixing of the core stream with the bypass stream has also been found to generate a significant proportion of the exhaust noise due to the difference in velocity of the core and bypass streams.

One common current exhaust nozzle design that is widely used is a lobed type nozzle which comprises a convoluted lobed core nozzle as known in the art. However, this adds considerable weight, drag, and cost to the installation and nowadays short bypass nozzles are favoured with which the lobed type core nozzles are less effective and are also more detrimental to the engine performance than when used on a long cowl arrangement.

An alternative nozzle design that is directed to reducing exhaust noise is proposed and described in GB 2,289,921. In this design, a number of circumferentially spaced notches, of various specified configurations, sizes, spacing and shapes, are provided in the downstream periphery of a generally circular core exhaust nozzle. Such a nozzle design is considerably simpler to manufacture than the conventional lobed designs. This prior proposal describes that the notches generate vortices in the exhaust streams. These vortices enhance and control the mixing of the core and bypass streams which it is claimed reduces the exhaust noise.

Model testing of nozzles similar to those described in GB 2,289,921 has shown that significant noise reduction and suppression can be achieved. However the parameters and details of the design proposed in GB 2,289,921 are not optimal and there is a continual desire to improve the nozzle design further.

A further design, and that of the present Assignee, is proposed in UK Application GB 0025727.9. This application

discloses trapezoidal shaped tabs disposed to the axially rearward exhaust ducts of the bypass and core and which are inclined radially inward to impart vortices to the exhaust streams.

However, the main requirement of reducing exhaust noise is during aircraft take-off and landing. At higher altitudes where the majority of the duration of the flight is, exhaust noise is not a problem. It is therefore not necessary to have noise reduction means operational at higher altitudes especially when one considers the noise reduction means inherently introduces aerodynamic inefficiencies.

It is therefore desirable and is an object of the present invention to provide an improved gas turbine engine exhaust nozzle which is quieter than conventional exhaust nozzles and/or which offers improvements generally.

According to a first aspect of the present invention there is provided a gas turbine engine exhaust nozzle arrangement for the flow of exhaust gases therethrough between an upstream end and a downstream end thereof comprising a nozzle and a plurality of tabs which extend in a generally axial direction from a downstream portion of the nozzle wherein the nozzle further comprises an actuation mechanism capable of moving the tabs between a first deployed position, where the tabs interact with a gas stream to reduce exhaust noise thereof, and a second non-deployed position, where the tabs are substantially aerodynamically unobtrusive.

Preferably the plurality of tabs are circumferentially disposed about the nozzle and the actuation mechanism comprises a shape memory material element.

Preferably the tabs are rotatably attached to the nozzle at a radially inner position, the actuation mechanism comprises the shape memory element mounted at a first end to a radially outer part of the nozzle and mounted at a distal end to a radially outer part of the

tab, such that in use, the element in a first shape maintains the tab in the second non-deployed position and in a second shape maintains the tab in the first deployed position.

Preferably, the periphery of the nozzle defines a pocket therein and at least a part of the element is generally disposed within the pocket and the tab defines a recess therein and at least a part of the element is generally disposed within the recess.

Alternatively the element is in the form of a spring.

Preferably a resilient member is attached at a first end to the tab and at a distal end to the nozzle and is arranged to provide a returning force to the tab.

Preferably the nozzle defines an orifice and a passage, the orifice is exposed to a gas stream and the passage extends from the orifice to the pocket and thereby provides a conduit for transmitting the thermal flux of the gas stream to the actuation mechanism.

Alternatively the tab comprises shape memory material and the tab further comprises a flexural element, the flexural element, in use, is arranged to provide a returning force to the tab.

Preferably the tab defines an orifice, the orifice exposed to a gas stream, and a passage, the passage extending from the orifice, to the shape memory material and thereby provides a conduit for rapidly transmitting changes in the thermal flux of the gas stream to and throughout the memory shape material element.

Preferably the actuation mechanism is actuated in a response to an applied field and the field is a temperature flux. Alternatively the field is an electric current.

Preferably the temperature flux is provided by the gas stream and the gas stream is any one chosen from the group comprising an ambient gas flow, a bypass flow, a core flow.

Preferably the shape memory material element comprises any one of a group comprising Titanium, Manganese, Iron,

Aluminium, Silicon, Nickel, Copper, Zinc, Silver, Cadmium, Indium, Tin, Lead, Thallium, Platinum.

Alternatively the shape memory material element comprises an electrostrictive material and the actuation mechanism further comprises an electrical circuit, the electrical circuit comprising control apparatus, an electric generating means and electrical contact means, the electrical contact means arranged to deliver, in use, an electrical signal, generated by the electrical generating means, through the electrostrictive material, the control apparatus operable to control the electrical signal. Alternatively, when the control apparatus is operated to deliver the electrical signal to the electrostrictive material, thereby actuating the electrostrictive material, the tab is driven from a second non-deployed position to a first deployed position and when the control means is operated so as not to deliver the electrical signal the electrostrictive material moves the tab between the first deployed position and the second non-deployed position.

Preferably when the control apparatus is operated to deliver the electrical signal to the electrostrictive material, thereby actuating the electrostrictive material, the tab is moves between a first deployed position and a second non-deployed position and when the control means is operated so as not to deliver the electrical signal the electrostrictive material the tab is driven from the second non-deployed position to the first deployed position. Furthermore the control apparatus, operable to control the electrical signal, is operated in response to the altitude of an associated aircraft.

Preferably the electrostrictive material element comprises any one of a group comprising Lead Zirconate Titanate, Lead Magnesium Niobate and Strontium Titanate.

Alternatively the electrostrictive material element comprises any one of a polymer group including polyvinylidene fluoride.

Preferably the downstream portion of the nozzle comprises a downstream periphery, the plurality of circumferentially disposed tabs extend in a generally downstream direction from the downstream periphery.

Preferably the downstream portion of the nozzle defines a plurality of circumferentially disposed recesses, each recess receiving a tab and when the tab is in a second non-deployed position it substantially occupies the recess.

Alternatively the tabs comprise a thermal barrier coating disposed to a surface thereof.

Alternatively the nozzle comprises a thermal barrier coating disposed to a surface thereof.

Preferably the tabs circumferentially taper in the downstream direction and the tabs are radially inwardly angled at an angle of up to 20° relative to the nozzle wall.

Alternatively the tabs are radially outwardly angled at an angle of up to 20° relative to the nozzle wall.

Furthermore the tabs are circumferentially alternately radially inwardly angled at an angle of up to 20° relative to the nozzle wall and radially outwardly angled at an angle of up to 20° relative to the nozzle wall.

Preferably the tabs are of a substantially trapezoidal shape but alternatively the general shape of the tabs is any one of the group comprising rectangular, square and triangular shape.

Preferably the tabs are circumferentially disposed about the periphery of the nozzle wall to define substantially trapezoidal shaped notches between adjacent tabs. Alternatively the tabs are circumferentially disposed about the periphery of the nozzle wall to define substantially V-shaped notches between adjacent tabs.

Alternatively the edges of the tabs are curved.

Preferably the nozzle tabs are radially inwardly angled at an angle of up to 10° relative to the nozzle wall.

Preferably the exhaust nozzle arrangement is a core engine nozzle but alternatively the exhaust nozzle is a bypass exhaust nozzle and the arrangement may comprises a core exhaust nozzle and a bypass exhaust nozzle.

Alternatively the exhaust nozzle arrangement comprises an outer bypass exhaust and an inner core exhaust nozzle of a lobed mixer type.

Preferably the downstream end of the bypass nozzle is further downstream than the downstream periphery of the core exhaust nozzle. Alternatively the downstream end of the bypass nozzle is upstream of the downstream periphery of the core exhaust nozzle.

Preferably the arrangement is for exhaust noise attenuation.

Preferably the tabs extend generally in the downstream direction but alternatively the tabs extend generally in the upstream direction.

According to a second aspect of the present invention there is provided a method of operating an aircraft having a gas turbine engine comprising an exhaust nozzle arrangement as claimed in any preceding claim wherein the method comprises the steps of: deploying noise reduction means prior to take-off; not deploying noise reduction means above a predetermined aircraft altitude and; deploying the noise reduction means below the predetermined aircraft altitude.

The present invention will now be described by way of example only with reference to the following figures in which:

Figure 1 is a schematic section of a ducted fan gas turbine engine incorporating an exhaust nozzle assembly, which itself comprises deployable noise reduction means in accordance with the present invention;

Figure 2 is a more detailed schematic perspective view of the exhaust nozzle assembly, comprising deployable noise

reduction means, of the ducted fan gas turbine engine shown in Figure 1;

Figure 3 is a part cutaway schematic view of the core exhaust nozzle, comprising deployable noise reduction means in a first deployed position, of the ducted fan gas turbine engine and exhaust nozzle shown in figures 1 and 2;

Figure 4 is a part cutaway schematic view of the core exhaust nozzle, comprising deployable noise reduction means in a second non-deployed position, of the ducted fan gas turbine engine and exhaust nozzle shown in figure 3;

Figure 5 is a section through the part of the core nozzle and shows a first embodiment of the present invention, the nozzle comprising a first actuation mechanism for deploying the tabs;

Figure 6 is a section through the part of the core nozzle and shows a second embodiment of the present invention, the nozzle comprising a second actuation mechanism for deploying the tabs;

Figure 7 is a section through the part of the core nozzle and shows a third embodiment of the present invention, the nozzle comprising a third actuation mechanism for deploying the tabs;

Figure 8 is a section through the part of the core nozzle and shows a forth embodiment of the present invention, the nozzle comprising a fourth mechanism for deploying the tabs;

Figure 9 is a section through the part of the core nozzle and shows a fifth embodiment of the present invention, the nozzle comprising a fifth mechanism for deploying the tabs;

Figure 10 is a section through the part of the core nozzle and shows a sixth embodiment of the present invention, the nozzle comprising a sixth mechanism for deploying the tabs;

Figure 11 is a more detailed schematic perspective view of the exhaust nozzle assembly, comprising a seventh

embodiment of the deployable noise reduction means, of a ducted fan gas turbine engine.

With reference to figure 1, a ducted fan gas turbine engine 10 incorporates an exhaust nozzle 12, 14, in accordance with the present invention, which itself comprises deployable noise reduction means. A ducted fan gas turbine engine 10 comprises, in axial flow series an air intake 5, a propulsive fan 2, a core engine 4 and an exhaust nozzle assembly 16 all disposed about a central engine axis 1. The core engine 4 comprises, in axial flow series, a series of compressors 6, a combustor 8, and a series of turbines 9. The direction of airflow through the engine 10, in operation, is shown by arrow A and the terms upstream and downstream used throughout this description are used with reference to this general flow direction. Air is drawn in through the air intake 5 and is compressed and accelerated by the fan 2. The air from the fan 2 is split between a core engine 4 flow and a bypass flow. The core engine 4 flow enters core engine 4, flows through the core engine compressors 6 where it is further compressed, and into the combustor 8 where it is mixed with fuel which is supplied to, and burnt within the combustor 8. Combustion of the fuel with the compressed air from the compressors 6 generates a high energy and velocity gas stream which exits the combustor 8 and flows downstream through the turbines 9. As the high energy gas stream flows through the turbines 9 it rotates turbine rotors extracting energy from the gas stream which is used to drive the fan 2 and compressors 6 via engine shafts 11 which drivingly connect the turbine 9 rotors with the compressors 6 and fan 2. Having flowed through the turbines 9 the high energy gas stream from the combustor 8 still has a significant amount of energy and velocity and it is exhausted, as a core exhaust stream, through the engine exhaust nozzle assembly 16 to provide propulsive thrust. The remainder of the air from, and accelerated by,

the fan 2 flows within a bypass duct 7 around the core engine 4. This bypass air flow, which has been accelerated by the fan 2, flows to the exhaust nozzle assembly 16 where it is exhausted, as a bypass exhaust stream to provide further, and in fact the majority of, the useful propulsive thrust.

The velocity of the bypass exhaust stream is significantly lower than that of the core exhaust stream. Turbulent mixing of the two exhaust streams in the region of, and downstream of, the exhaust nozzle assembly 16, as well as mixing of both streams with the ambient air surrounding and downstream of the exhaust nozzle assembly 16 generates a large component of the noise generated by the engine 10. This noise is known as exhaust or jet noise. Effective mixing and control of the mixing of the two exhaust streams with each other and the ambient air is required in order to reduce noise generated. The mixing and its control is effected by the exhaust nozzle assembly 16.

In the embodiment shown the exhaust nozzle assembly 16 comprises two generally concentric sections, namely a radially outer bypass exhaust nozzle 12 and an inner core exhaust nozzle 14. The core exhaust nozzle 14 is defined by a generally frusto-conical core nozzle wall 15. This defines the outer extent of an annular core exhaust duct 30 through which the core engine flow is exhausted from the core engine 4. The inner extent of the core exhaust duct 30 is defined by an engine plug structure 22.

Figure 2 is a more detailed schematic perspective view of the exhaust nozzle assembly 16, comprising deployable noise reduction means 18, 20, of a ducted fan gas turbine engine 10. Figure 2 shows a similar configuration of noise reduction means 18, 20 as shown in UK Application GB 0025727.9, the present invention, however, relates to the exhaust nozzle having deployable noise reduction means 18, 20. It is intended that the deployable noise reduction

means 18, 20 of the present invention operate in a similar manner and with the noise reduction advantages described in UK Application GB 0025727.9 when in a first deployed position. By way of example therefore, and as a preferred embodiment, the deployed tabs 18, 20 of the present invention are herein described with reference to the fixed noise reduction means of UK Application GB 0025727.9.

Referring again to Figure 2, which shows a plurality of circumferentially spaced tabs 20 extending from the downstream periphery 23 of the core exhaust nozzle 14 and core nozzle walls 15. As shown, the tabs 20 are of a trapezoidal shape with the sides of the tabs 20 circumferentially tapering towards each other in the downstream direction. The tabs 20 are evenly and circumferentially disposed so that a notch 21 or space is defined by and between adjacent tabs 20. However, it is not intended to limit the spacing of the tabs 20 to being evenly distributed about the periphery 23 of the nozzle 14. The notches 21 are complimentary to the shape of the tab 20 and accordingly are of a trapezoidal shape on the core nozzle 14, with the notches 21 circumferentially opening out in a downstream direction.

The number of tabs 20, and so notches 21 defined in the core exhaust nozzle 14 and also bypass exhaust nozzle 12 (described below), the width of the notches 21, angle of the notches 21, width of notch 21, angular offset between notches 21, and angular gap between notches 21 are all essentially the same and within the same ranges as described in GB 2,289,921. It should be noted however that in GB 2,289,921 only the core nozzle 14 is provided with tabs 20 and notches 21 whereas, as described below, according to the present invention the downstream periphery 27 of the bypass exhaust nozzle 12 may also be provided with tabs 18 and thereby defined notches 19.

Referring to Figure 3 which is a part cutaway schematic view of the core exhaust nozzle, comprising

deployable noise reduction means 18, 20 in a first deployed position, of the ducted fan gas turbine engine 10 and exhaust nozzle 14 shown in Figures 1 and 2. For simplicity, Figure 3 and the description hereafter relates only to the present invention applied to the core exhaust nozzle 14, however the present invention may equally be applied to the bypass nozzle 12.

The tabs 20 of the core exhaust nozzle 14 are radially inwardly angled so that the tabs 20 impinge into the core duct 30 (relative to an extended line 24, shown in figure 3, of the profile of the core nozzle wall 15 immediately upstream of the tabs 20) and are, in operation, incident on the core exhaust flow which is exhausted through the core exhaust nozzle 14. The angle of incidence β of the tabs 20 is defined relative to an extended line 24 of the profile of the core exhaust nozzle wall 15 immediately upstream of the tabs 20. The profile of the core nozzle wall 15 immediately upstream of the tabs 20 itself is at an angle α (typically between 10° and 20°) to the engine axis 1.

It has been found that by angling the tabs 20, and the angle of incidence β, there is an effect on jet noise suppression. As the angle of incidence β is increased up to 20° the noise reductions are improved. However at angles of incidence β above 20° there is little further improvement in noise suppression. Furthermore at these higher angles of incidence β aerodynamic losses due to the effect the tabs 20 have on the core exhaust flow increase. Because of the aerodynamic losses at cruise the preferred embodiment of UK Application GB 0025727.9 comprises tabs 20 being angled at angles of incidence β up to 10°. For the present invention the tabs 20 may be preferably deployed at higher angles of incidence β, particularly at aircraft take-off and landing, as the tabs 20 may then be positioned in a second non-deployed position during aircraft cruise where the noise reduction means 20 are not required. The

deployability of the tabs 20 is described in more detail hereinafter.

The tabs 20 and angling of the tabs 20 reduces the mid and low frequency noise generated by the exhaust and engine 10, typically in the frequency range 50-500 kHz. It does however, in some cases increase the noise generated at higher frequencies. The noise at low and mid frequencies though is the most critical in terms of the perceived noise level and the higher frequency noise is masked by noise generated from elsewhere in the engine 10. Therefore overall the tabs 20 provide a reduction in the perceived exhaust noise generated. The increase in high frequency noise sometimes associated with the angled tabs 20 at higher angles of incidence β is a further reason why the tabs 20 are preferably angled at angles of incidence β up to 10°.

The tabs 20 induce stream-wise vortices in the exhaust flow through and around the nozzle 14. These vortices are generated and shed from the sides of the tabs 20 and increase the local turbulence levels in a shear layer that develops between the core and bypass exhaust streams downstream of the exhaust nozzle assembly 16. This vorticity and turbulence increases and controls the rate of mixing between the core exhaust stream, bypass exhaust stream, and the ambient air. This mixing reduces the velocities downstream of the exhaust assembly 16, as compared to a conventional nozzle, and so reduces the mid to low frequency noise generated by the exhaust streams. The increased turbulence generated by the tabs 20 in the initial part of the shear layers immediately downstream of the exhaust nozzle assembly 16 causes an increase in the high frequency noise generated. Having tabs 20 angled radially inwards increases the strength of the vortices produced and so improves the reduction in perceived noise. However the angle of incidence β of the tabs 20 must not be too large since this can induce flow separation which will

generate, rather than reduce the noise as well as adversely affecting aerodynamic performance of the nozzle 14.

The bypass exhaust nozzle 12 is also defined by a generally frusto-conical bypass nozzle wall 17 which is concentric with and disposed radially outwardly of the core exhaust nozzle 14. The bypass nozzle wall 17 defines the outer extent of an annular bypass exhaust duct 28 through which the bypass engine flow is exhausted from the engine 10. The inner extent of the bypass exhaust duct 28 is defined by an outer wall 15 of the core engine 4. The bypass nozzle 12 is similar to the core exhaust nozzle 14 and a plurality of circumferentially spaced tabs 18 extend from the downstream end of the bypass exhaust nozzle 12 and bypass nozzle walls 17. As with the core nozzle 14, the tabs 18 are of a trapezoidal shape with the sides of the tabs 18 circumferentially tapering in the downstream direction. The tabs 18 are evenly circumferentially disposed so that a V-shaped notch 19 or space is defined by and between adjacent tabs 18. The bypass nozzle tabs 18 affect the bypass exhaust flow and noise generated in a similar way to the core exhaust nozzle tabs 20.

The tabs 20 should have a length L sufficient to generate the required stream-wise vortices as described below and GB 2,289,921 specifies that the tabs 18,20 must have a length L of between 5% to 50% of the nozzle diameter Dc, Db. It has been found however that using long tabs, towards the 50% end of the range given, induces excessive aerodynamic losses which adversely affect the performance particularly when they are angled. Accordingly it has been determined that the core tabs 20 should have a length L of approximately 10% of the core exhaust nozzle diameter Dc, whilst the bypass tabs 18 should have a length L of approximately 5% of the bypass exhaust nozzle diameter Db. The bypass tabs 18 have a smaller percentage length since the bypass provides more of the propulsive thrust of the engine and so any performance loss on the bypass will have

a greater effect on the overall engine performance. In addition although the percentage size is less, since the bypass is of a greater diameter than the core the actual physical size of the core tabs 20 and bypass tabs 20 are not so different.

In model tests of the exhaust nozzle assembly 16 shown in figure 2 and described above a 5dB reduction in the peak sound pressure level over a conventional plain frusto conical nozzle arrangement has been achieved. It has also been found that the noise reductions provided by using tabs 18 on the bypass exhaust nozzle 12 and by using tabs 20 on the core exhaust nozzle 14 are cumulative. It will therefore be appreciated that in other embodiments tabs 18, 20 can be used on the bypass exhaust nozzle 12 or the core exhaust nozzle 14 alone to give some improved degree of noise suppression. The core exhaust nozzle tabs 20 and the bypass exhaust nozzle tabs 18 can also be angled at different angles of incidence β.

Whereas Figure 3 and the description thereof are related to a preferred embodiment it is not intended that the present invention only relates to that preferred embodiment. For example, the deployable tabs 20 may be any shape and in particular may also be triangular, and the tabs 20 may be unevenly distributed about the periphery 23 of the nozzle 14. Similarly, the tabs 20 may be angled both radially inwardly and radially outwardly from the periphery 23 of the nozzle 14. It is also not intended that the tabs 20 must be straight, but may be curved in the plane of the paper on figure 3. Although the preferred embodiment the present invention is not restricted to a particular angle of the tabs 20 nor their length L.

The present invention is however, concerned with having deployable noise reduction means. The term deployable meaning that the noise reduction means, in a first position, may be exposed to and interact with the gas stream(s) and be operable as noise reduction means and

in a second position or suitable arrangement may be generally aligned with the gas stream(s) to be aerodynamically unobtrusive and therefore not operable as a noise reduction means. This second position is in order to reduce the aerodynamic drag when the aircraft is particularly at cruise and where the noise reduction means is not generally required.

Figure 4 is a part cutaway schematic view of the core exhaust nozzle 14, comprising deployable noise reduction means 20 in a second non-deployed position, of the ducted fan gas turbine engine 10 and exhaust nozzle 14 shown in figure 3. It is an object of the present invention to provide either the bypass nozzle 12 or the inner core exhaust nozzle 14 or both with deployable noise reduction means 20. The main requirement of reducing exhaust noise is during aircraft take-off and landing procedures. At higher altitudes where often the majority of the duration of the flight is, exhaust noise is not a problem. It is therefore not necessary to operate noise reduction means 20 at higher altitudes especially when one considers the noise reduction means 20 introduces aerodynamic inefficiencies. Thus, in Figure 4, the tabs 20 are in a second non-deployed position, where they have been generally aligned with the nozzle wall 15 and thus also the gas stream and when they are not required for exhaust noise reduction. Although in Figure 4 the tabs 20 are shown in general alignment with the nozzle wall 15, it is an object of the present invention to provide non-deployed tabs 20 which are aligned in the most aerodynamic position which is not necessarily as shown on Figure 4 for all embodiments of the present invention. It is also an object of the present invention to provide deployable tabs 20 or a mechanism for deploying the tabs 20 which is operable by means of the change in a field. The fields of particular relevance to the present invention are temperature flux, electrical current or magnetic flux. Thus it is the change or at least exposure

to one of these types of field which operate the control mechanism to at least deploy the tabs 20.

Figure 5 shows a first embodiment of the present invention, the nozzle comprising a suitable mechanism for deploying the tabs 20. The deployable tabs 20 are shown in the second non-deployed position by the solid lines, where they are generally aligned with the nozzle wall 15 and therefore aligned generally with the exhausted gas stream, and in the first deployed position by the dashed tabs 20′. In the first deployed position the tabs 20′ interact with the gas stream creating and shedding noise reducing vortices. The first mechanism 32 suitable for activating the tabs 20, 20′ comprises a shape memory material (SMM) element 34, as known in the art, which is switchable from a first shape indicated as reference numeral 34 to a second shape indicated as reference numeral 34′. The SMA element 34 is disposed within or partly within a pocket 36 situated in the aft end of the nozzle wall 15 and a recess 38 in the tab 20. The SMM element 34 is secured by rotatable means 40, 42 to both the nozzle wall 15 and the tab 20 respectively. The first mechanism 32 also comprises the tab 20 being rotatably mounted to the nozzle wall 15 by further rotatable means 44.

In this first embodiment of the present invention the shape of the SMM element 34 is temperature sensitive. Below a predetermined temperature the SMM element 34 is designed to assume the first shape 34 and above the predetermined temperature the SMM element 34 assumes the second shape 34′. Essentially the SMM element 34 changes its length from the first shape 34 to the second shape 34′ and thereby operates as an actuator mechanism for deploying the tabs 20. This temperature is known as the switch temperature and for the present invention a suitable switch temperature would be between the temperatures generally experienced at either take-off or landing, and that experienced at cruise. It is generally understood that

temperature decreases with an increase in altitude and it is this temperature change that this first embodiment of the present invention seeks to utilise. Typically high altitude cruise temperatures may be between minus 25°C to 40°C and ground temperatures between minus 15°C to plus 40°C. A suitable switch temperature or range of temperatures would be minus 15°C to minus 25°C. Thus at take-off and landing the SMM element 34 would assume the second position, thereby deploying the tabs 20′, and at cruise the SMM element 34′ would assume the first position with the tabs 20 in the second non-deployed position.

Although this embodiment only shows one SMM element 34, more than one SMM element 34 may be disposed to each tab 20. Similarly, although in this embodiment the tabs 20 are rotatably mounted 44 at a radially inner position and the SMM element 34 mounted to the nozzle 14 and tabs 20 at a radially outer position (40, 42), it is equally feasible to interchange the inner mounting positions (44) with the outer mounting position (40, 42). Thus it is possible to operate the tab 20 in similar fashion or alternatively to deploy the tab in a radially outward direction.

It is preferable although not essential to provide an orifice 37 and a passage 39, both defined by the core nozzle 14, leading from the core duct 30 to the pocket 36. The orifice 37 is configured such that core exhaust gases may be channelled into the pocket 36 so that the SMM element 34 is subjected to the thermal output of the engine as quickly as possible, thereby the response of the SMM element 34 is relatively rapid.

The SMM element 34 may be manufactured from any, or any combination of the following materials; Titanium, Manganese, Iron, Aluminium, Silicon, Nickel, Copper, Zinc, Silver, Cadmium, Indium, Tin, Lead, Thallium, Platinum, polymers.

Figure 6 is a section through part of the core nozzle 14 and shows a second embodiment of the present invention,

the nozzle 14 comprising a second actuation mechanism 50 for deploying the tabs 20. The second actuation mechanism 50 is disposed within or partly within a pocket 36 situated in the aft end of the nozzle wall 15 and a recess 38 in the tab 20 and comprises a SMM spring element 52, in the general form of a helical spring, and a further, coaxial spring 54. The coaxial spring 54 comprises a conventional resilient material and which operates in a conventional manner. The SMM spring 52 may be secured by rotatable means 56, 58 to both the nozzle wall 15 and the tab 20 respectively. The second mechanism 50 also comprises the tab 20 being rotatably mounted to the nozzle wall 15 by further rotatable means 60.

The second embodiment of the present invention operates in a similar manner to the first embodiment in that the length of the SMM spring element 52 changes when its temperature is above or below a predetermined switchable temperature. In this embodiment the coaxial spring 54 is provided to give a returning force for the tabs 20 having been deployed. It is equally viable to use any resilient member capable of applying a returning force instead of the spring 54. The particular advantage of this embodiment is that the actuation mechanism may accommodate greater extensions while undergoing less strain than the SMM element 34 described with reference to the first embodiment.

Although this second embodiment of the present invention describes the use of a single SMM spring element 52 and spring 54 more than one of each may be used. The SMM spring element 52 and spring 54 may also be arranged other than coaxially.

Figure 6 also shows a duct 62 formed in the nozzle wall 15 which is so arranged to provide the actuation mechanism 50 with a flow of gas. In this embodiment, where the actuation mechanism is arranged to give a greater extent of actuation, it is advantageous to provide the

actuation mechanism 50 with cooler exhaust gas ducted from the bypass gas stream rather than the core exhaust gas stream, the bypass stream temperature being more representative of the ambient air temperature and thus better suited to providing a more defined switchable temperature. In general the ambient temperature near to and on the ground is warmer than at altitude. Thus the tabs 20 may be conveniently calibrated to the relative difference in these ambient temperatures at different altitudes. However, this does not discount using the core gas stream flow to control the temperature of the SMM. Using the core gas flow to control the temperature of the SMM has an advantage in that its temperature is not dependant on the ambient air temperature, but instead is dependant on the engine operation cycle. At take-off, the engines are working at near maximum capacity and the core exhausted gas is at its hottest, whereas at cruise there is a reduction in the core exhaust gas temperature.

Figure 7 is a section through the part of the core nozzle 14 and shows a third embodiment of the present invention, the nozzle comprising a third actuation mechanism for deploying the tabs 20. The deployable tabs 20 are shown in the second non-deployed position by the solid lines, where they are generally aligned with the nozzle wall 15 and therefore aligned generally with the exhausted gas stream, and in the first deployed position by the dashed tabs 20'. In the first deployed position the tabs 20' interact with the gas stream generating and shedding noise reducing vortices.

In this third embodiment of the present invention the tabs 20 themselves are manufactured from SMM thus the tabs themselves are the actuation mechanism. The tab 20 is disposed to the periphery of the nozzle 14 and generally extends in the rearward direction therefrom. Again above the switch temperature the SMM tab 20' will be in the first

deployed position and below the switch temperature the SMM tab 20 will be in the second non-deployed position.

Where the thermal cycle of the bypass exhaust gas is utilised to actuate the SMM element 66, a thermal barrier coating 63 is be applied to the radially inner surface 65 of the tab 20 to provide thermal insulation from the core exhaust gases.

Figure 8 is a section through the part of the core nozzle and shows a forth embodiment of the present invention, the nozzle comprising a fourth mechanism for deploying the tabs. The fourth actuation mechanism comprises a tab 20, disposed to the aft periphery of the nozzle wall 15, including a flexural element 64 and a SMM element 66. The flexural element 64 and SMM element 66 essentially make up radially inner and outer portions of the tab 20 respectively, the tabs being of general configuration as hereinbefore described. This fourth embodiment operates in a similar manner to the third embodiment, except that the flexural element 64 provides a returning force to the tab 20, the tab 20 having been deployed. The flexural element 64 helps to prevent hysteresis of the SMM element 64 and may itself comprise any suitable resilient material such as titanium.

With particular reference to the present embodiment, and that described with reference to Figure 7, where the tabs 20 are disposed to the periphery of the core nozzle 14 and therefore subject to high temperatures, it is a further advantage for the flexural element 64 to comprise a material which is either heat resistant or generally does not conduct heat to the SMM element 64. Alternatively, where the thermal cycle of the bypass exhaust gas is utilised to actuate the SMM element 66, a thermal barrier coating (as shown on Figure 7) may be applied to the radially inner surface of the tab 20 to provide thermal insulation from the core exhaust gases.

It is preferable, although not essential, to provide the shape memory material element 64 with means to quickly respond to a change in gas temperature. One such way is to shown in Figure 8 where the tab 20 defines an orifice 68 which is exposed to a gas stream, and a passage 69 which extends from the orifice 68 to the shape memory material element 66 and thereby provides a conduit for quickly transmitting changes in the thermal flux of the gas stream to and throughout the memory shape material element 66. In this embodiment, where the nozzle 14 is the core nozzle 14, it is preferred to dispose the orifice 68 to the radially outer surface 67 of the tab 20 thereby utilising the bypass gas flow for the purposes of actuating the shape memory material element 64.

Another such way of providing the shape memory material element 64 with the means to quickly respond to a change in gas temperature is to use fins (not shown), which extend outward from the surfaces of the tab 20 and thereby provide an increased surface area for improved thermal transfer. Alternatively, channels (not shown) may be defined by the tab 20 so as to increase the surface area of the tab 20.

Referring now to Figure 9, which is a section through the part of the core nozzle and shows a fifth embodiment of the present invention, the nozzle comprising a fifth mechanism for deploying the tabs. In this fifth embodiment the tabs 20 comprise electrostrictive material. The tabs 20 are connected via leads 72 and 74 to an electrical supply 70, which are configured to apply an electrical current through the tab 20. Thereby, on application of an electric current, the tab 20 displaces to the shape of tab 20', where the tab 20 is in the first deployed position. Removal of the electric current returns the tab 20 from the first deployed position (20') to the second non-deployed position (20).

For the purposes of the present invention the term 'shape memory material' comprises the thermally responsive materials already mentioned herein as well as electrostrictive materials and magnetostrictive materials. The electrostrictive material may typically comprise lead zirconate titanate, lead magnesium niobate or strontium titanate. Alternatively, the electrostrictive material may be in the form of a polymer such as polyvinylidene fluoride. Furthermore, magnetostrictive materials may be used having similar properties to electrostrictive material. Suitable magnetostrictive materials include Titanium, Manganese, Iron, Aluminium, Silicon, Nickel, Copper, Zinc, Silver, Cadmium, Indium, Tin, Lead, Thallium, Platinum. Although the amount of magnetostriction is usually small, it has been shown (Clark, A.E., "Magnetostrictive rare earth-Fe_2 compounds", Ferromagnetic Materials, Vol. 1, Ch. 7, North Holland Publishing Co., 1980) that considerable magnetostriction in an alloy of Terbium, Dysprosium and Iron, which is commercially known as Terfenol-D™, is possible. Terfenol-D™ comprises approximately 30% Terbium and 70% Dysprosium and also traces of Iron.

It is intended that the electric current be applied by a control switch which itself is dependant on an engine or aircraft condition or mode of operation. For example and which is also a preferred embodiment, the control of the electrical current is dependant on the altitude of the aircraft. Thus below a predetermined altitude there is no electric current supplied to the tabs 20', which are in the first deployed position. Above the predetermined altitude the electric current is switched on and supplied to the tabs 20 which are then driven into their second non-deployed position. Alternatively, the tabs 20 may be disposed in their second non-deployed position when there is no supply of electric current. On start up of the engine an electric current is thereby supplied to the tabs

20′ to deploy them. Then on reaching the predetermined altitude the electric current to the tabs 20′ is cut off and the tabs 20 return to their second non-deployed position.

Figure 10 is a section through part of the core nozzle 15 and shows a sixth embodiment of the present invention, the nozzle 15 comprising a sixth mechanism for deploying the tabs. Similar to the fourth embodiment of the present invention the tabs 20 comprises an electrostrictive element 76 and a flexural element 78. The flexural element 78 provides a returning force to the tab 20 after the tab 20 has been deployed and the electrical supply has been removed. The flexural element 78 helps to prevent hysteresis of the tab 20 and may itself comprise any suitable resilient material such as titanium.

With reference to Figure 11, which is a more detailed schematic perspective view of the exhaust nozzle, comprising a seventh embodiment of the deployable noise reduction means, of a ducted fan gas turbine engine. For clarity the core plug 22 is not shown. Although the present invention has been described hereinbefore with reference to the tabs 20 or noise reduction means being disposed to the downstream periphery 23 of a nozzle wall 15, 17 is should be noted that any of the noise reduction means, herein described, may be easily adapted to be disposed substantially within the core or bypass nozzle walls 15, 17. For this alternative embodiment of the present invention, non-deployed tabs 20 are disposed within recesses 80 in a rearward portion 27 of the nozzle wall 15 to form an aerodynamically smooth gas-washed surface and deployed tabs 20′ (as shown in figure 11) project radially inward from the nozzle wall 15. The upstream edge portion 82 of the tabs 20 being attached to the nozzle wall 15. In the first deployed position the tabs 20′ generate the noise reducing vortices as described hereinbefore. In addition, this embodiment may also comprise the tabs 20 being

disposed to the radially outer side of the core nozzle wall 15 and to the radially inner and outer sides of the bypass nozzle wall 15 or in any combination of the radially inner and outer side of either the core or bypass nozzles 15, 17.

It should also be understood to the skilled reader that the temperature controlled shape memory material herein described may also be activated by electrical heating elements disposed to or within the shape memory material. Thus the shape memory material may be controlled by aircraft systems such as an altimeter.

With reference to all the noise reduction means described herein, a further advantage of the present invention is that the degree to which the tabs 18, 20 are extended into the gas stream may be optimised easily during testing and evaluation. Furthermore the tabs 18, 20 may be deployed to varying extents during the flight cycle of the host aircraft and thereby attenuate different noise frequencies.

A further embodiment of the present invention is provided by arranging certain tabs 20 to deploy radially inwardly and other tabs to deploy radially outwardly. Preferably, the alternate tabs 20 are arranged to deploy inwardly and outwardly around the entire periphery of the nozzle 15. The benefits of this arrangement are described in EP0984152 A2 and will therefore not be reiterated herein.

As an alternative to using shape memory material as an actuator a volume change material may be used. The use of wax like substances are well known for their increased volume change from solid to liquid phases in response to a temperature change. Thus from the teachings of description hereinbefore it should be understood to one skilled in the art that a suitable actuator mechanism could be easily substituted for the shape memory material actuators. For instance a wax like material may be disposed in a piston type arrangement, so that the piston is extended when the

wax is in a liquid phase and when the wax is in a solid phase the piston is shorter.

Furthermore in yet another embodiment of the invention a bypass exhaust nozzle using tabs as described above can be used in conjunction with a conventional forced lobed type core exhaust nozzle/mixer. Such an arrangement has also been tested and has shown improved noise suppression over an exhaust assembly which uses a lobed type core nozzle/mixer with a conventional bypass exhaust nozzle.

Although the invention has been described and shown with reference to a short cowl type engine arrangement in which the bypass duct 28 and bypass exhaust nozzle 12 terminate upstream of the core exhaust duct 30 and nozzle 14, the invention may also be applied, in other embodiments, to long cowl type engine arrangements in which the bypass duct 28 and bypass exhaust nozzle 12 terminate downstream of the core exhaust duct 20 and nozzle 14. The invention however is particularly beneficial to short cowl arrangements since with such arrangements conventional noise suppression treatments of the exhaust are not practical in particular where high by pass ratios are also used.

The invention is also not limited to ducted fan gas turbine engines 10 with which in this embodiment it has been described and to which the invention is particularly suited. In other embodiments it can be applied to other gas turbine engine arrangements in which either two exhaust streams, one exhaust stream or any number of exhaust streams are exhausted from the engine though an exhaust nozzle(s).

Claims

1. A gas turbine engine exhaust nozzle arrangement for the flow of exhaust gases therethrough between an upstream end and a downstream end thereof comprising a nozzle and a plurality of tabs which extend in a generally axial direction from a downstream portion of the nozzle wherein the nozzle further comprises an actuation mechanism capable of moving the tabs between a first deployed position, where the tabs interact with a gas stream to reduce exhaust noise thereof, and a second non-deployed position, where the tabs are substantially aerodynamically unobtrusive.

2. A gas turbine engine exhaust nozzle arrangement as claimed in claim 1 wherein the plurality of tabs are circumferentially disposed about the nozzle.

3. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-2 wherein the actuation mechanism comprises a shape memory material element.

4. A gas turbine engine exhaust nozzle arrangement as claimed in claim 3 wherein the tabs are rotatably attached to the nozzle at a radially inner position, the actuation mechanism comprises the shape memory element mounted at a first end to a radially outer part of the nozzle and mounted at a distal end to a radially outer part of the tab, such that in use, the element in a first shape maintains the tab in the second non-deployed position and in a second shape maintains the tab in the first deployed position.

5. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-4 wherein the periphery of the nozzle defines a pocket therein and at least a part of the element is generally disposed within the pocket.

6. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-5 wherein the tab defines a recess therein and at least a part of the element is generally disposed within the recess.

7. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 3-6 wherein the element is in the form of a spring.

8. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-7 wherein a resilient member is attached at a first end to the tab and at a distal end to the nozzle and is arranged to provide a returning force to the tab.

9. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-8 wherein the nozzle defines an orifice and a passage, the orifice is exposed to a gas stream and the passage extends from the orifice to the pocket and thereby provides a conduit for transmitting the thermal flux of the gas stream to the actuation mechanism.

10. A gas turbine engine exhaust nozzle arrangement as claimed in claim 1-3 wherein the tab comprises shape memory material.

11. A gas turbine engine exhaust nozzle arrangement as claimed in claim 10 wherein the tab further comprises a flexural element, the flexural element, in use, is arranged to provide a returning force to the tab.

12. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 10-11 wherein the tab defines an orifice, the orifice exposed to a gas stream, and a passage, the passage extending from the orifice, to the shape memory material and thereby provides a conduit for rapidly transmitting changes in the thermal flux of the gas stream to and throughout the memory shape material element.

13. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-12 wherein the actuation mechanism is actuated in a response to an applied field.

14. A gas turbine engine exhaust nozzle arrangement as claimed in claim 13 wherein the field is a temperature flux.

15. A gas turbine engine exhaust nozzle arrangement as claimed in claim 13 wherein the field is an electric current.

16. A gas turbine engine exhaust nozzle arrangement as claimed in claim 13 wherein the temperature flux is provided by the gas stream and the gas stream is any one chosen from the group comprising an ambient gas flow, a bypass flow, a core flow.

17. A gas turbine engine exhaust nozzle arrangement as claimed in claim 2-16 wherein the shape memory material element comprises any one of a group comprising Titanium, Manganese, Iron, Aluminium, Silicon, Nickel, Copper, Zinc, Silver, Cadmium, Indium, Tin, Lead, Thallium, Platinum.

18. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 2-16 wherein the shape memory material element comprises an electrostrictive material.

19. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 2-16 wherein the actuation mechanism further comprises an electrical circuit, the electrical circuit comprising control apparatus, an electric generating means and electrical contact means, the electrical contact means arranged to deliver, in use, an electrical signal, generated by the electrical generating means, through the electrostrictive material, the control apparatus operable to control the electrical signal.

20. A gas turbine engine exhaust nozzle arrangement as claimed in claim 19 wherein when the control apparatus is operated to deliver the electrical signal to the electrostrictive material, thereby actuating the electrostrictive material, the tab is moved from a second non-deployed position and a first deployed position and when the control means is operated so as not to deliver the electrical signal the electrostrictive material moves the tab between the first deployed position and the second non-deployed position.

21. A gas turbine engine exhaust nozzle arrangement as claimed in claim 19 wherein when the control apparatus is operated to deliver the electrical signal to the electrostrictive material, thereby actuating the electrostrictive material, the tab is moved between a first deployed position and a second non-deployed position and when the control means is operated so as not to deliver the electrical signal the electrostrictive material the tab is moved from the second non-deployed position and the first deployed position.

22. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 20-21 wherein the control apparatus, operable to control the electrical signal, is operated in response to the altitude of an associated aircraft.

23. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 18-22 wherein the electrostrictive material element comprises any one of a group comprising Lead Zirconate Titanate, Lead Magnesium Niobate and Strontium Titanate.

24. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 18-22 wherein the electrostrictive material element comprises any one of a polymer group including polyvinylidene fluoride.

25. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-24 wherein the downstream portion of the nozzle comprises a downstream periphery, the plurality of circumferentially disposed tabs extend in a generally downstream direction from the downstream periphery.

26. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-24 wherein the downstream portion of the nozzle defines a plurality of circumferentially disposed recesses, each recess receiving a tab.

27. A gas turbine engine exhaust nozzle arrangement as claimed in claim 26 wherein a tab, in a second non-deployed position, substantially occupies a recess.

28. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-27 wherein the tabs comprise a thermal barrier coating disposed to a surface thereof.

29. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-28 wherein the nozzle comprises a thermal barrier coating disposed to a surface thereof.

30. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-29 wherein the tabs circumferentially taper in the downstream direction.

31. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-30 wherein the tabs are radially inwardly angled at an angle of up to 20° relative to the nozzle wall.

32. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-30 wherein the tabs are radially outwardly angled at an angle of up to 20° relative to the nozzle wall.

33. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-230 wherein the tabs are circumferentially alternately radially inwardly angled at an angle of up to 20° relative to the nozzle wall and radially outwardly angled at an angle of up to 20° relative to the nozzle wall.

34. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-33 wherein the tabs are of a substantially trapezoidal shape.

35. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claim 1-34 wherein the general shape of the tabs is any one of the group comprising rectangular, square and triangular shape.

36. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-34 wherein the tabs are

circumferentially disposed about the periphery of the nozzle wall to define substantially trapezoidal shaped notches between adjacent tabs.

37. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-34 wherein the tabs are circumferentially disposed about the periphery of the nozzle wall to define substantially V-shaped notches between adjacent tabs.

38. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-37 wherein the edges of the tabs are curved.

39. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-38 wherein the nozzle tabs are radially inwardly angled at an angle of up to 10° relative to the nozzle wall.

40. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-39 wherein the tabs extend in circumferentially alternating radially inward and outward directions for mixing the exhaust gas streams.

41. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-40 wherein the exhaust nozzle is a core engine nozzle.

42. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-41 wherein the exhaust nozzle is a bypass exhaust nozzle.

43. A ducted fan gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-42 wherein the arrangement comprises a core exhaust nozzle and a bypass exhaust nozzle.

44. A ducted fan gas turbine engine exhaust nozzle arrangement comprising an outer bypass exhaust nozzle as claimed in any one of claims 1-40, and an inner core exhaust nozzle of a lobed mixer type.

45. A ducted fan gas turbine engine exhaust nozzle arrangement as claimed in claim 44 wherein the downstream

end of the bypass nozzle is further downstream than the downstream periphery of the core exhaust nozzle.

46. A ducted fan gas turbine engine exhaust nozzle arrangement as claimed in claim 42 wherein the downstream end of the bypass nozzle is upstream of the downstream periphery of the core exhaust nozzle.

47. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-46 wherein the arrangement is for exhaust noise attenuation.

48. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-47 wherein the tabs extend generally in the downstream direction.

49. A gas turbine engine exhaust nozzle arrangement as claimed in any one of claims 1-47 wherein the tabs extend generally in the upstream direction.

50. A method of operating an aircraft having a gas turbine engine comprising an exhaust nozzle arrangement as claimed in any preceding claim wherein the method comprises the steps of: deploying noise reduction means prior to take-off; not deploying noise reduction means above a predetermined aircraft altitude and; deploying the noise reduction means below the predetermined aircraft altitude.

51. A gas turbine engine exhaust nozzle arrangement as hereinbefore described and with reference to figures 1 to 15.

52. A ducted fan gas turbine engine as hereinbefore described and with reference to figures 1 to 15.

Abstract

A gas turbine engine exhaust nozzle arrangement (16) for the flow of exhaust gases therethrough between an upstream end and a downstream end thereof comprising a nozzle (14) and a plurality of tabs (20) which extend in a generally axial direction from a downstream portion (25) of the nozzle (14) wherein the nozzle (14) further comprises an actuation mechanism (32) capable of moving the tabs (20) between a first deployed position, where the tabs (20) interact with a gas stream to reduce exhaust noise thereof, and a second non-deployed position, where the tabs (20) are substantially aerodynamically unobtrusive

(Figure 5)

Fig.1.

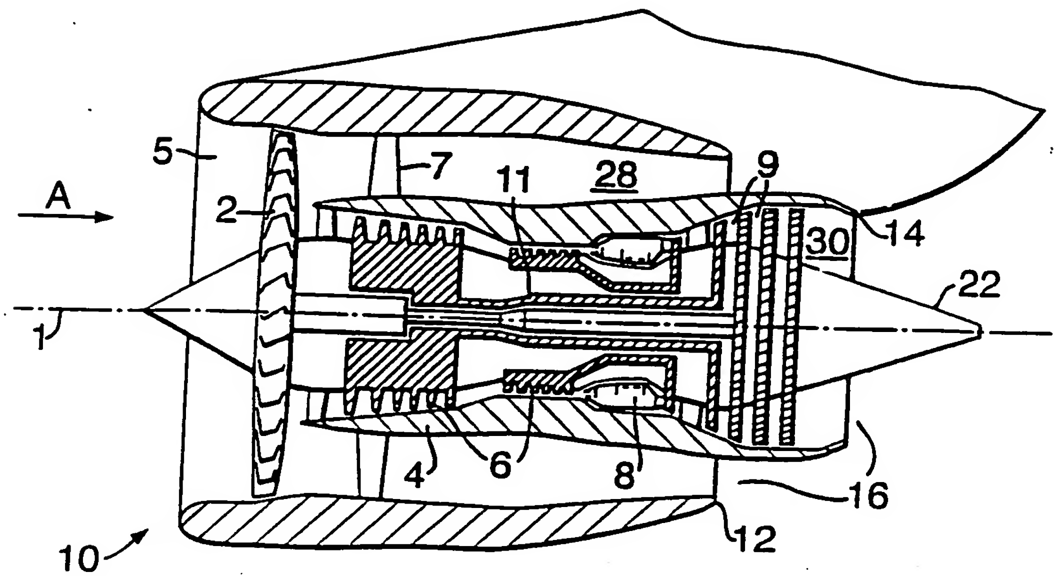

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Fig.2.

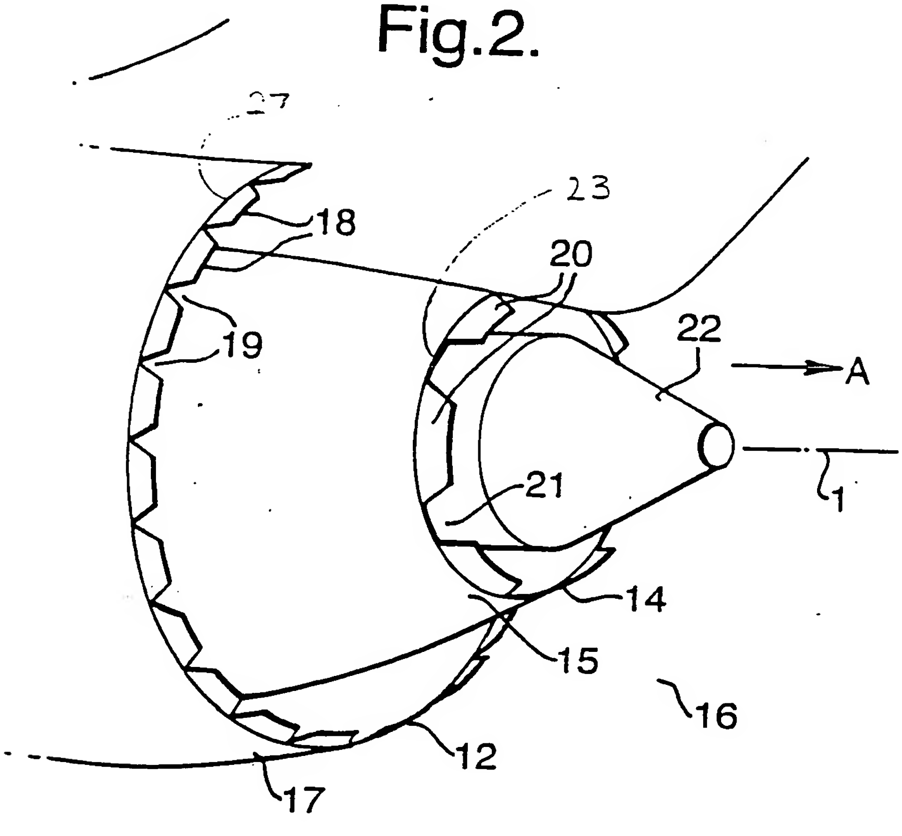

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Fig.3.

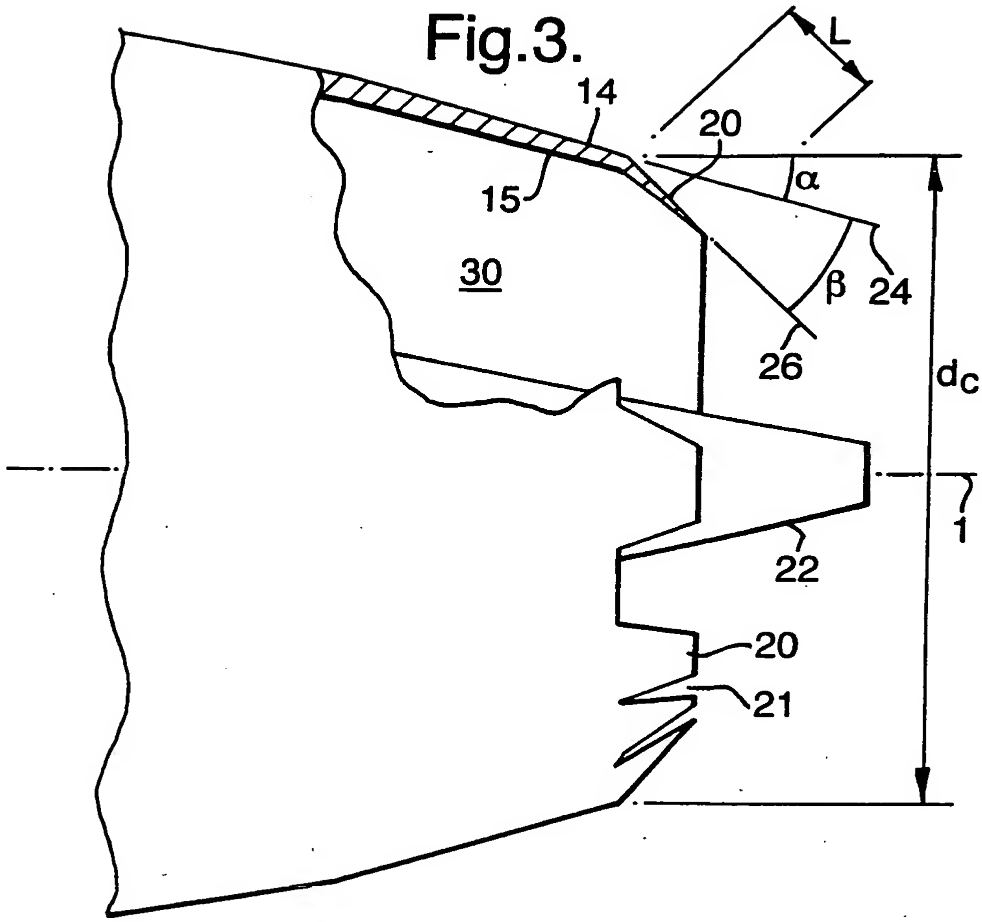

Fig.4.

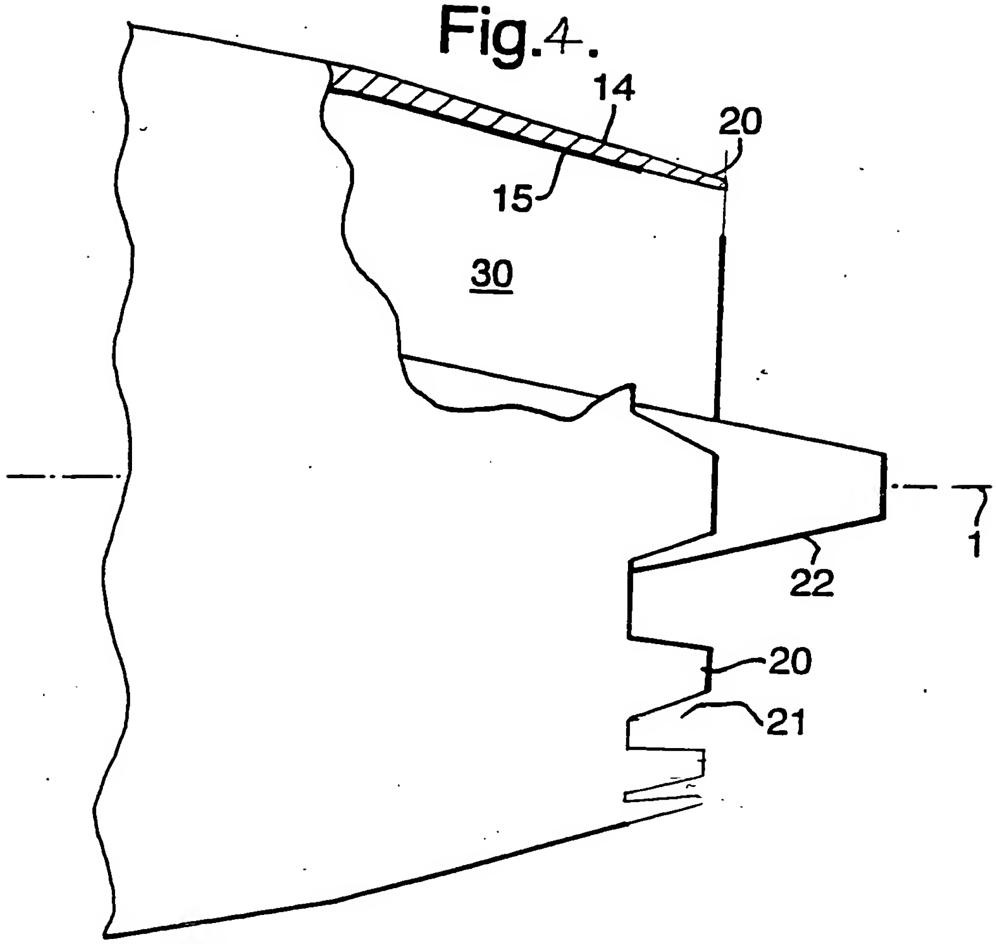

FIG 5

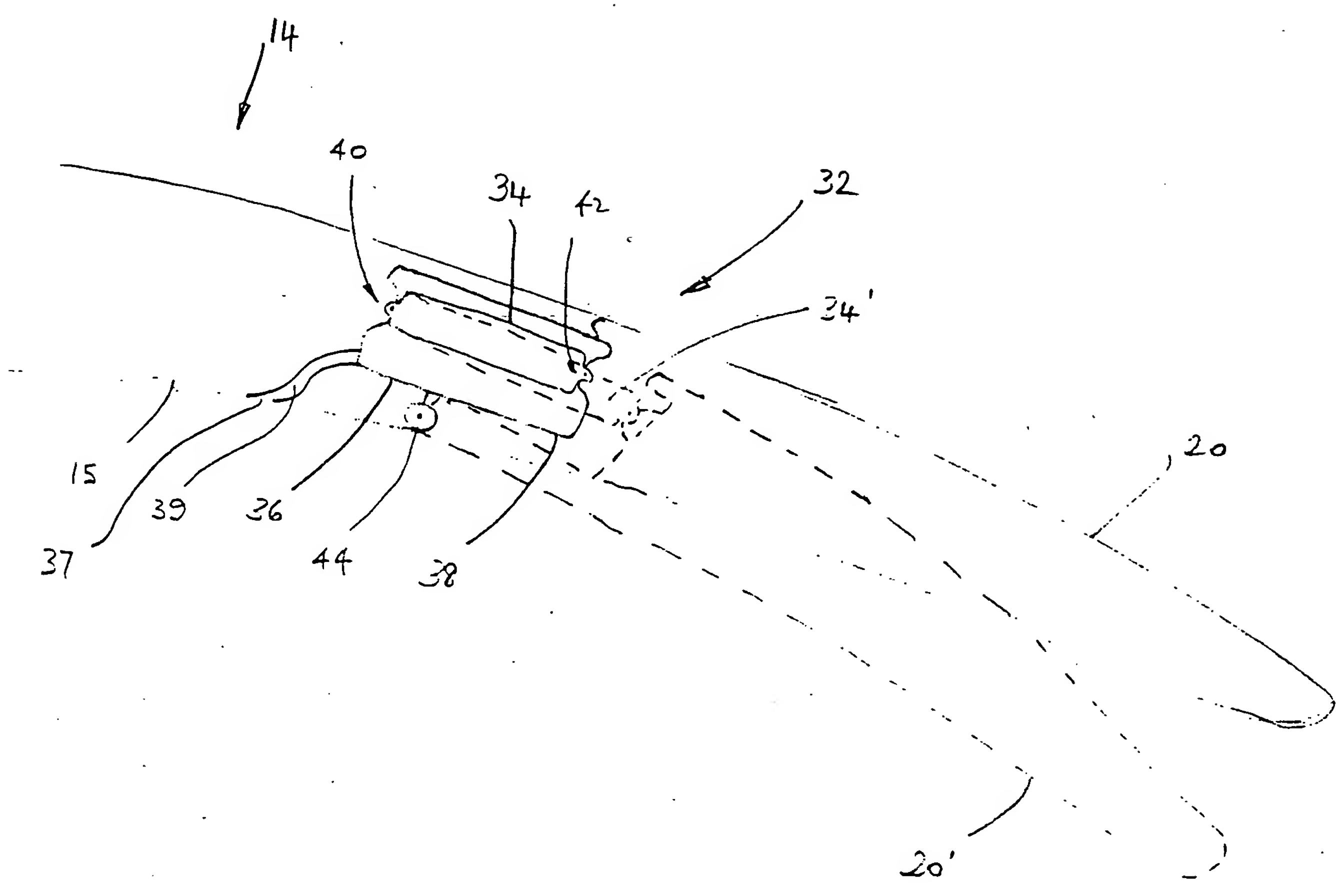

Fig 6.

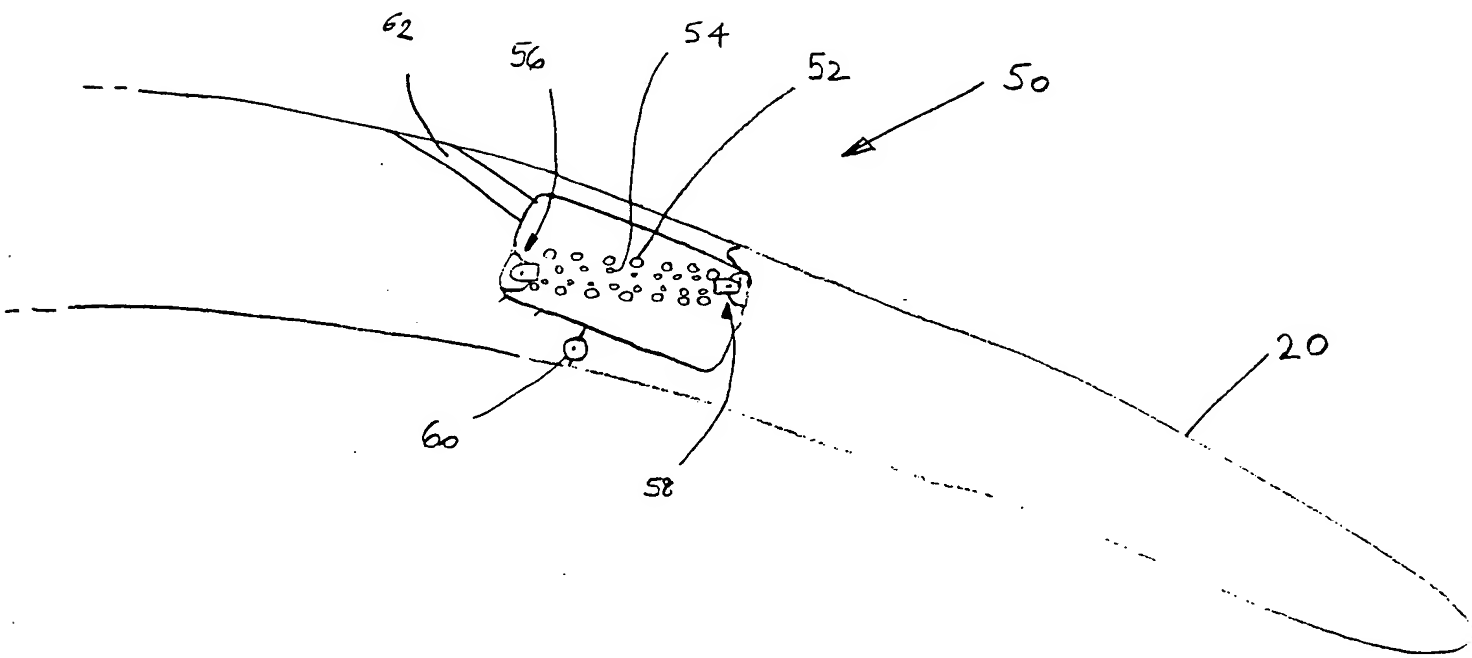

Fig 7.

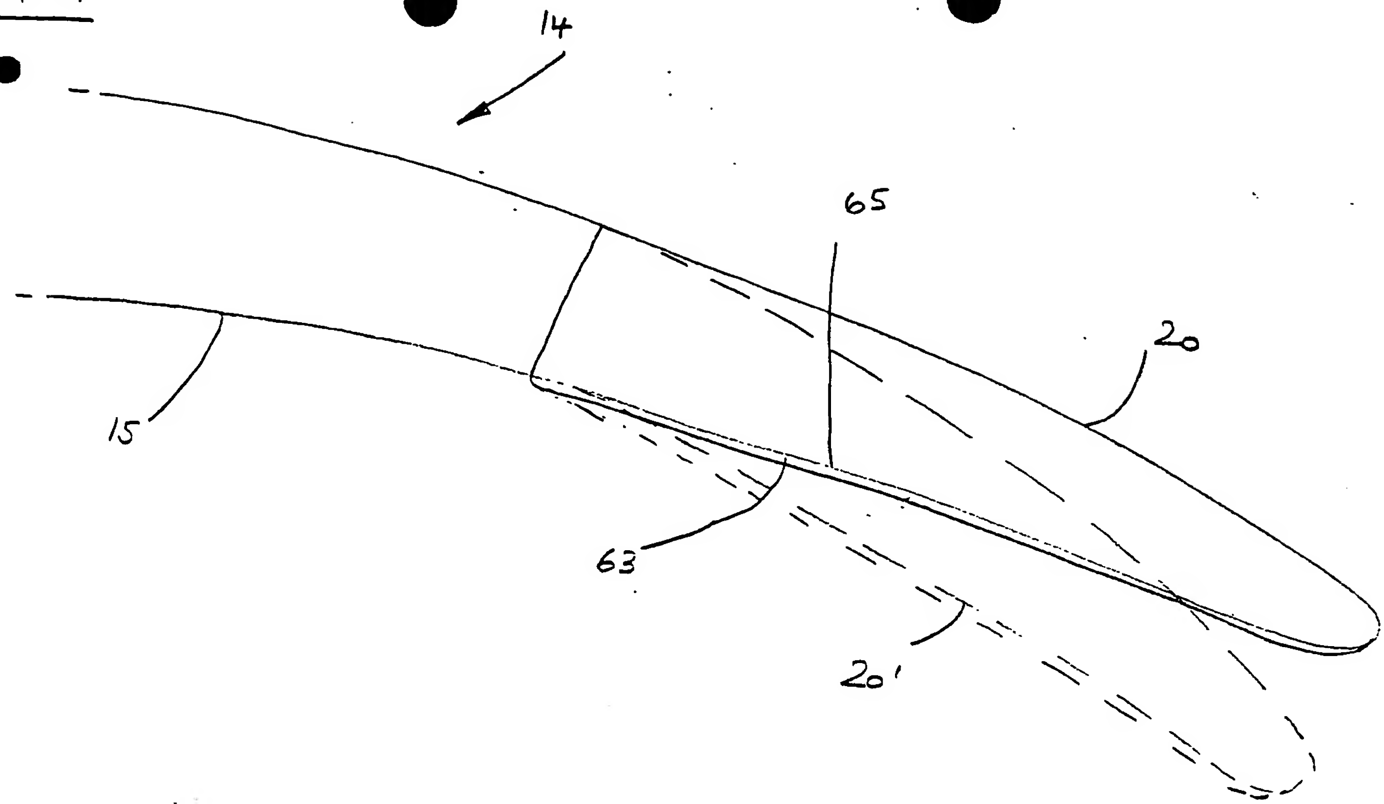

FIG 8

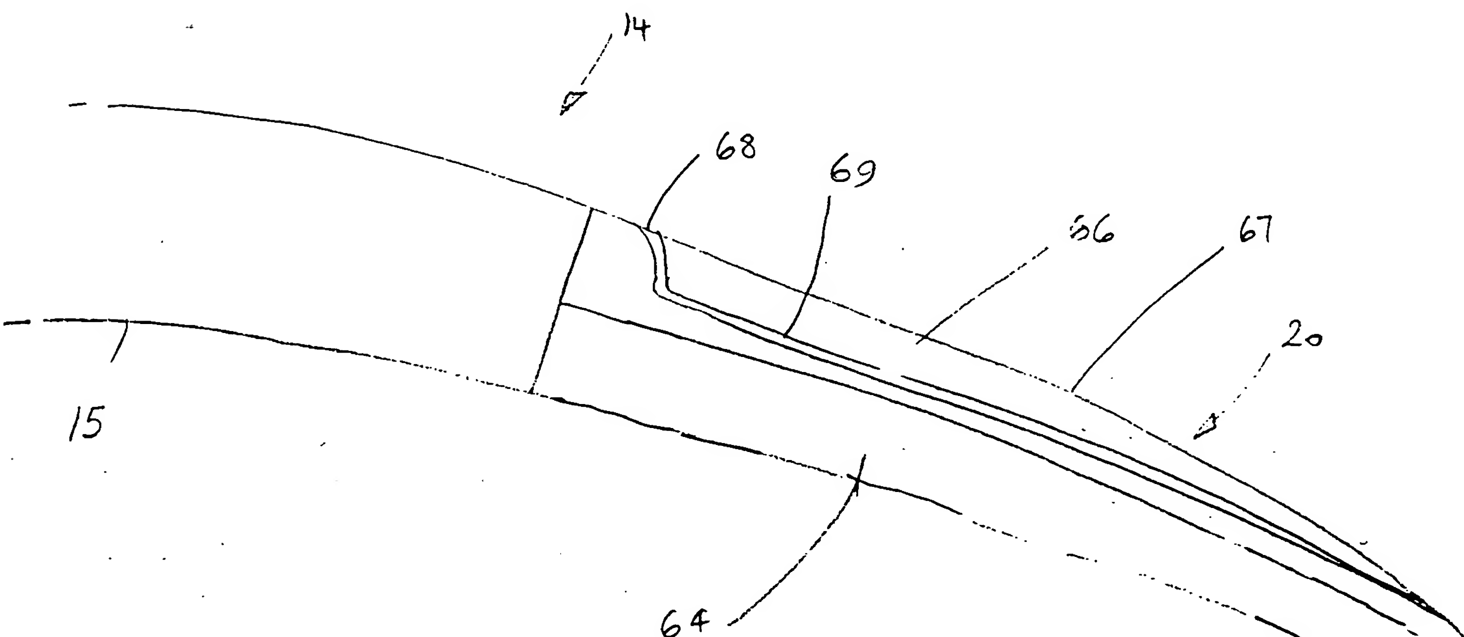

FIG 9

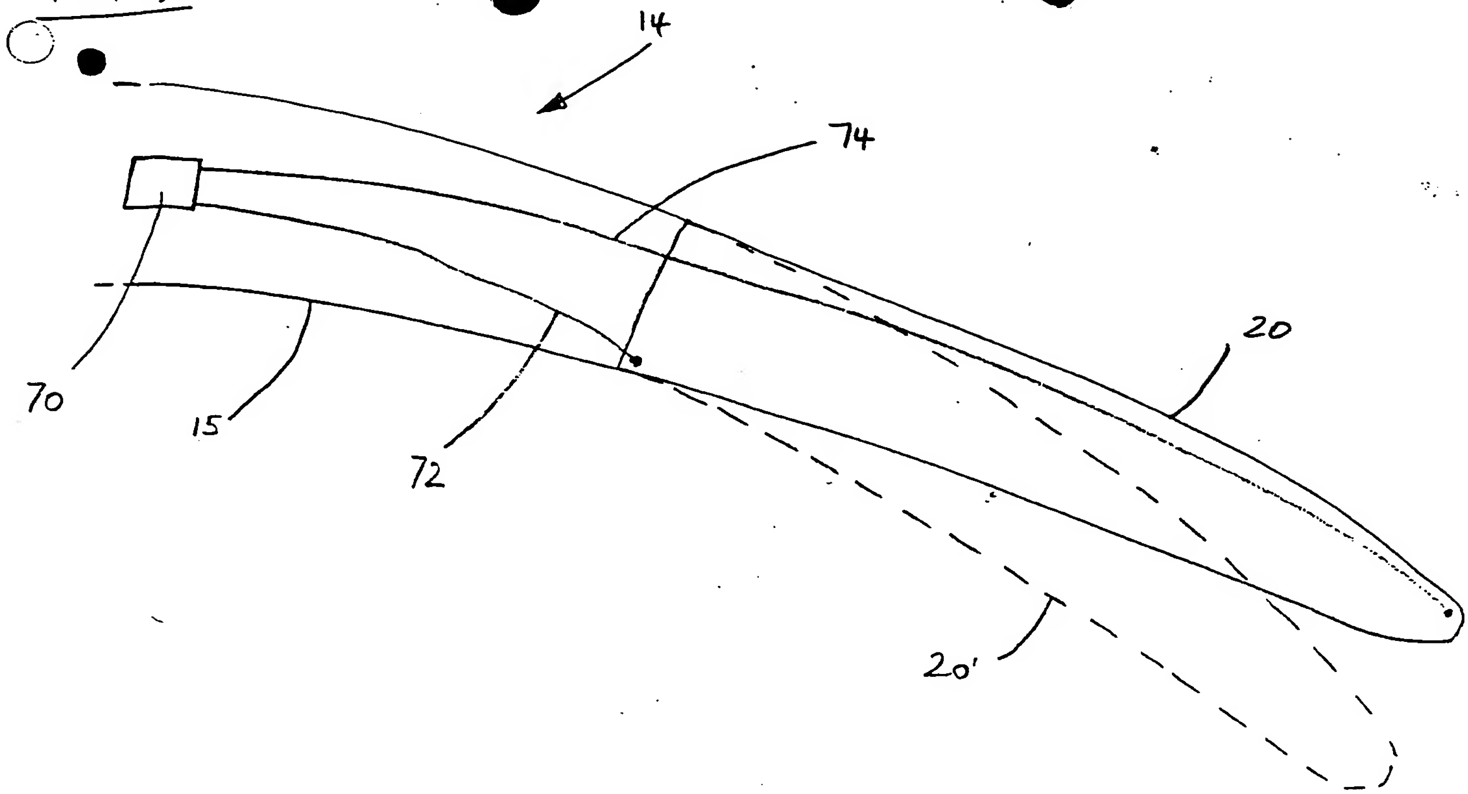

FIG 10

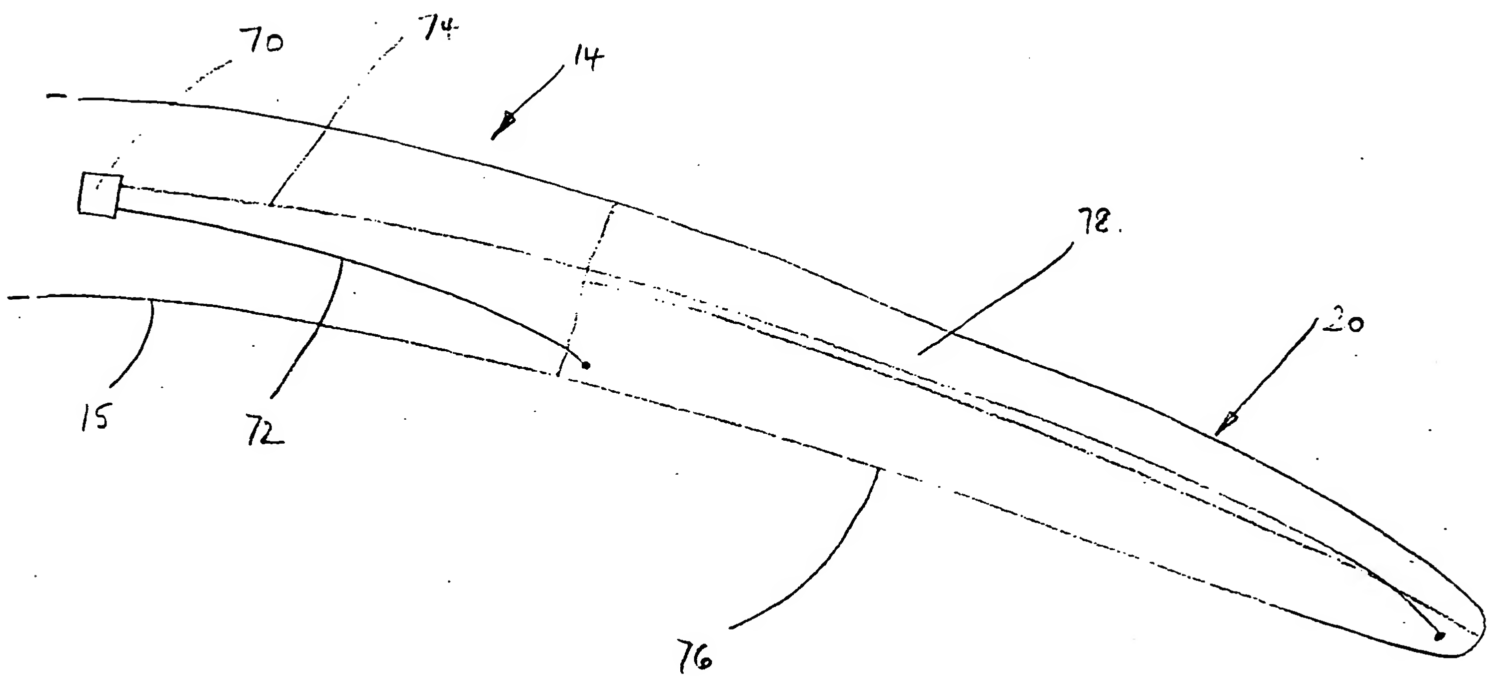

Fig. 11